1.0 Y-12 COMPLEX MASS BALANCE PROJECT

1.1 PROJECT OVERVIEW

This report has been prepared to summarize the findings of the Y-12 National Security Complex (Y-12 Complex) Mass Balance Project and to support preparation of associated U. S. Department of Energy (DOE) site reports. The project was conducted in support of DOE efforts to assess the potential for health and environmental issues resulting from the presence of transuranic (TRU) elements and fission products in recycled uranium (RU) processed by DOE and its predecessor agencies. The U. S. government used uranium in fission reactors to produce plutonium and tritium for nuclear weapons production. Because uranium was considered scarce relative to demand when these operations began almost 50 years ago, the spent fuel from U.S. production reactors was processed to recover the residual uranium for recycling.

Uranium that has been irradiated in reactors contains TRU elements [e.g., plutonium (Pu) and neptunium-237 (Np)], fission products [e.g., technetium-99 (Tc)], and reactor-generated uranium products [e.g., uranium-236 (^{236}U)]. Following chemical processing to separate and extract Pu, as well as to recover uranium for reuse, trace quantities of Pu, Np, Tc, and ^{236}U remain in the RU stream. These constituents make the RU stream more radioactive than natural uranium. Thus, the handling, processing, and re-enrichment of RU may present a potential for personnel and environmental exposure greater than that normally associated with the processing of unirradiated uranium.

In response to these concerns, DOE initiated an effort to identify situations in which the processing of RU by DOE and its predecessor agencies could have created an increased potential for exposure of workers and/or significantly increased environmental exposure. The first step in this process involves the "mass balance review." This review attempts to determine how much RU was generated by the U.S. government during a period of approximately 47 years and to determine how the material was distributed among the various weapons plants and laboratories.

DOE's reconstruction of the historical flow and processing of RU includes three fundamental activities:

- determining annual mass flow of RU throughout the DOE system from the start of processing to March 31, 1999,
- identifying the characteristics and constituents (e.g., Pu, Np, Tc, and ^{236}U) in the major uranium streams, and
- at appropriate sites, conducting mass balance activities sufficient to identify any significant implications for personnel or environmental releases.

The DOE mass balance review includes U.S. government sites that were sources for RU (i.e., sites that processed irradiated fuel to recover uranium for recycling); sites that processed RU or re-enriched the RU stream in the fissile ^{235}U isotope; sites that manufactured weapons components; and other affected sites. As part of its work as a uranium weapons component production facility, the Y-12 Complex performed operations to recover or reuse highly enriched uranium (HEU) from RU that came from reactor returns generated by several

source sites. From 1953 until 1989, the Y-12 Complex recovered HEU from various uranium solutions, oxides, alloys, and scrap metal and recycled the uranium metal it produced back to DOE production reactors.

The Y-12 Complex's involvement with other sites included:

- receiving highly enriched RU from U.S. government facilities at the Savannah River Site (SRS) and the Idaho Chemical Processing Plant (ICPP) following use of chemical separation processes to extract uranium from irradiated fuel,
- receiving depleted RU in the form of fluorination tower ash from the Paducah Gaseous Diffusion Plant (PGDP) for storage or disposition as waste,
- receiving depleted RU for disposition from the Oak Ridge Gaseous Diffusion Plant (ORGDP) and, in much smaller quantities, from Hanford,
- receiving slightly enriched RU from SRS and shipping the same material without repackaging to Fernald,
- shipping highly enriched RU metal product to SRS for recycling,
- shipping depleted RU to PGDP (returning fluorination tower ash that had been shipped from PGDP and stored at the Y-12 Complex), and
- shipping depleted RU to ORGDP (returning material that had been shipped from ORGDP and stored at the Y-12 Complex).

The processing of RU at the Y-12 Complex impacted a number of facilities and locations at the plant site. The primary facilities with significant involvement in processing RU were:

- Building 9212, a large uranium processing complex that performed uranium recovery operations on RU materials and produced RU metal product,
- Building 9206, a large uranium processing facility that also performed uranium recovery operations on RU materials and produced RU metal product,
- Building 9720-5, the Y-12 Complex "warehouse," which received, stored, and shipped uranium materials, including RU,
- S-3 Ponds, four holding ponds for liquid and sludge wastes resulting from processes involving uranium, including both unirradiated and recycled uranium (prior to WETF operation beginning in 1986),
- West End Treatment Facility (WETF), a group of nine tanks/bioreactors for holding and treating Y-12 Complex aqueous nitrate wastes (after the S-3 Ponds were taken out of service) plus four sludge storage tanks, and
- New Hope Pond, a large surface water impoundment designed to capture and retain coal fines and other entrained solids from rainwater and plant secondary wastewaters.

The Y-12 Complex Mass Balance Project represents an effort to collect, verify, analyze, and interpret available data to provide an overall accounting, or site mass balance, for Y-12 Complex RU streams. In addition, data on related Y-12 Complex processes and activities and data on Pu, Np, Tc, and ^{236}U —the primary constituents of concern in the RU stream—have also been collected, analyzed, and interpreted. Based on available plant records and information about processes and methods of operation and maintenance, the Project Team has identified essentially all those plant activities that (1) created a likelihood of Y-12 Complex workers coming into contact with significant levels of RU constituents

through direct physical contact or via airborne dust and/or (2) caused reportable environmental releases of concentrated RU constituents.

1.2 PURPOSE AND SCOPE

The purpose of the Y-12 Complex Mass Balance Project is to support DOE's efforts to identify all situations in which U.S. government processing of RU at the Y-12 Complex could have created significant exposure hazards for workers and/or significant release to the environment. Following the guidance provided in DOE's Mass Balance Project Plan,[1] the Y-12 Complex Project Team has focused on:

- describing the amounts, characteristics, and constituents of the incoming and outgoing RU streams at the Y-12 Complex,
- understanding the historical processes, product specifications, and process activities that involved the primary RU constituents of concern (Pu, Np, Tc, and ^{236}U),
- determining the facilities and processes where RU presented an increased potential for worker exposure to RU constituents or led to increased measurable environmental release, and
- determining annual mass balances for RU and for Pu, Np, and Tc to the degree existing data permit.

The project identified and reviewed RU streams at the Y-12 Complex from the initial introduction of RU into the plant in 1953 until March 31, 1999. These streams encompassed a broad spectrum of material forms, including uranyl nitrate [$UO_2(NO_3)_2$] solutions, uranium trioxide (UO_3), uranium-aluminum (U-Al) alloy ingots, uranium scrap, uranium tetrafluoride (UF_4), uranium metal, solvent extraction raffinate, and a variety of secondary process wastes and residues. The RU flow has been traced from receipt by the Y-12 Complex until disposition by the plant. Efforts have also been made to identify all other DOE sites with which the Y-12 Complex exchanged RU and to determine how the plant worked with them.

To identify the RU streams that most warrant attention, the Project Team discounted RU streams that posed no significant hazard over and above the hazard of similar work performed with unirradiated uranium, in accordance with the methodology and definition prescribed by the DOE Project Plan. These RU streams contained Pu, Np, Tc, and ^{236}U constituents at such low levels that the increase in potential radiological dose was less than 10% of the potential dose presented by unirradiated uranium alone. RU streams that represented final product or waste forms with no additional processing anticipated were also discounted. Since DOE has deemed such end products to be outside the scope of the mass balance project, these RU streams were excluded from further consideration. The process for identifying these RU streams, which include Y-12 Complex product and waste streams, is documented in this report.

[1] U.S. Department of Energy, *Historical Generation and Flow of Recycled Uranium in the DOE Complex: Project Plan*, February 2000.

1.3 PROJECT IMPLEMENTATION STRATEGY

An interdisciplinary Project Team was formed to conduct the Y-12 Complex Mass Balance Project. Team members included individuals with extensive experience in nuclear materials control and accountability, Y-12 Complex operations for uranium recovery and processing to uranium metal, process maintenance, health and safety at DOE facilities, nuclear engineering, process engineering, nuclear process waste management, the nuclear fuel cycle, statistical analysis, and data and information management. Guided by information provided in the DOE Project Plan (e.g., the Question Set and the Site Report Outline), the team developed a strategy and process for identifying, collecting, organizing, and analyzing available data and information relevant to the project. Leads were established for major project areas (e.g., site historical overview, RU mass balance activities, and mass balance for constituents of concern), and team members were designated to research and abstract information on specific topics. Formal team meetings were held twice each week to track progress, reconcile data gaps and differences, and discuss project issues.

To identify and retrieve data, the Project Team searched the Y-12 Complex Records Center and a variety of other data collections at theY-12 Complex, including electronic systems and administrative files. Major data sources consulted and analyzed included:

- Nuclear Materials Control and Accountability (NMC&A) data, including shipping, receiving, and inventory records (e.g., individual form 101 and 741 Nuclear Material Transfer Reports),
- Y-12 Complex historical site reports on shipments and receipts,
- Y-12 Complex reports describing facilities and production processes,
- Y-12 Complex health physics records,
- Y-12 Complex production records,
- Y-12 Complex analytical laboratory records,
- Y-12 Complex internal correspondence reports,
- correspondence between shippers and receivers,
- historical DOE and contractor reports,
- more recent (i.e., post-1995) health physics reports on the site,
- more recent (i.e., post-1995) environmental survey reports on the site, and
- interviews with Y-12 Complex personnel with direct experience in RU-related operations.

The Project Team analyzed data on receipts, shipments, inventories, product, releases, and other categories—along with available analytical data—in the context of documented historical information on Y-12 Complex processes and activities. Understanding of processes known to concentrate Pu, Np, and Tc and of activities known to create potential for exposure to these RU constituents provided additional context for analysis. By correlating mass balance data, analytical data, and historical information on Y-12 Complex processes, the team was able to identify specific processes, locations, and time periods of importance for potential worker exposure or environmental releases. These processes, locations, and time periods became the focus of additional assessment to determine the situations that had the potential to create exposure hazards for workers and/or significant environmental release.

For some areas that presented gaps in data that could not at present be filled by research, the Project Team developed estimates for quantities of RU and RU constituents brought into the plant. These estimates are based on extrapolations from other site reports and actual data and represent (1) application of known data from similar material and/or circumstances or (2) application of known data from a specific time period over a longer or a shorter period of time. All such estimates and their bases are specifically identified in this report.

The RU identified in this report as having been received, processed, or shipped by the Y-12 Complex reflects the classical definition of reprocessed uranium: uranium that has been irradiated in reactors and subsequently processed to recover uranium for reuse in the DOE complex. Some DOE sites have labeled all material shipped or received during certain periods or from certain facilities as RU. As a result, there exist some discrepancies among sites regarding quantities of RU shipments and receipts that may need to be resolved. This report has been developed to identify and address the significant sources and quantities of RU at the Y-12 Complex from the standpoint of potential worker exposure or environmental consequences.

In some cases, the analytical data or calculations presented contain more significant figures than warranted by the precision of the information or methodology. But these are retained in this document, when available, for information purposes.

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